

Total Inward Leakage of Nanoparticles through Filtering Facepiece Respirators

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Introduction

- Inhalation of nanoparticles (<100 nm size) is a potential health concern to workers
- Filter penetration as well as face seal leakage contribute to the total inward leakage of particles, including nanoparticles, inside the breathing zone of the wearer
- Nanoparticle filter penetration for respirators has been studied by many laboratories using respirators at sealed conditions
- Studies on leakage of nanoparticles through the respirator/face seal interface using NIOSH-approved and CE marked Filtering Facepiece Respirators (FFRs) are lacking

Objectives

- To better understand face seal leakage of nanoparticles for NIOSH-approved and CE marked FFRs using a manikin
- To measure filter penetration and total inward leakage (TIL) for particles in the 8-400 nm size range under sealed conditions and with different artificial face seal leak sizes and breathing flow rates.
- To compare the TIL values for nanoparticles (<100 nm size) with the levels obtained for larger size (400 nm) particles

Methods

- A sampling probe and two additional probes for introducing leaks were fixed on each FFR sample (Fig 1)
- A breathing manikin in a test chamber was used (Fig 2)
- The respirator was sealed to the manikin with a silicone sealant
- Particle concentration inside of the respirator (C_{in}) and outside (C_{out}) was simultaneously measured using a scanning mobility particle sizer (SMPS) and an ultrafine condensation particle counter (UCPC)
- Calculated C_{in}/C_{out} ratios: 1) Filter penetration – sealed condition.
2) TIL value – with different leak sizes.
- TIL/penetration Ratio – Ratio of TIL for a given leak vs. the penetration of the sealed FFR at the same particle size.
- Three flow rates – 20, 30, 40 L/min breathing flow rates
- Four artificial leak sizes
- Monodisperse sucrose particles <20 nm size range
Polydisperse NaCl particles >20 nm size range



Fig 1. A typical respirator sample fixed with a sample probe (center of the FFR) and two leak probes (near the face seal).

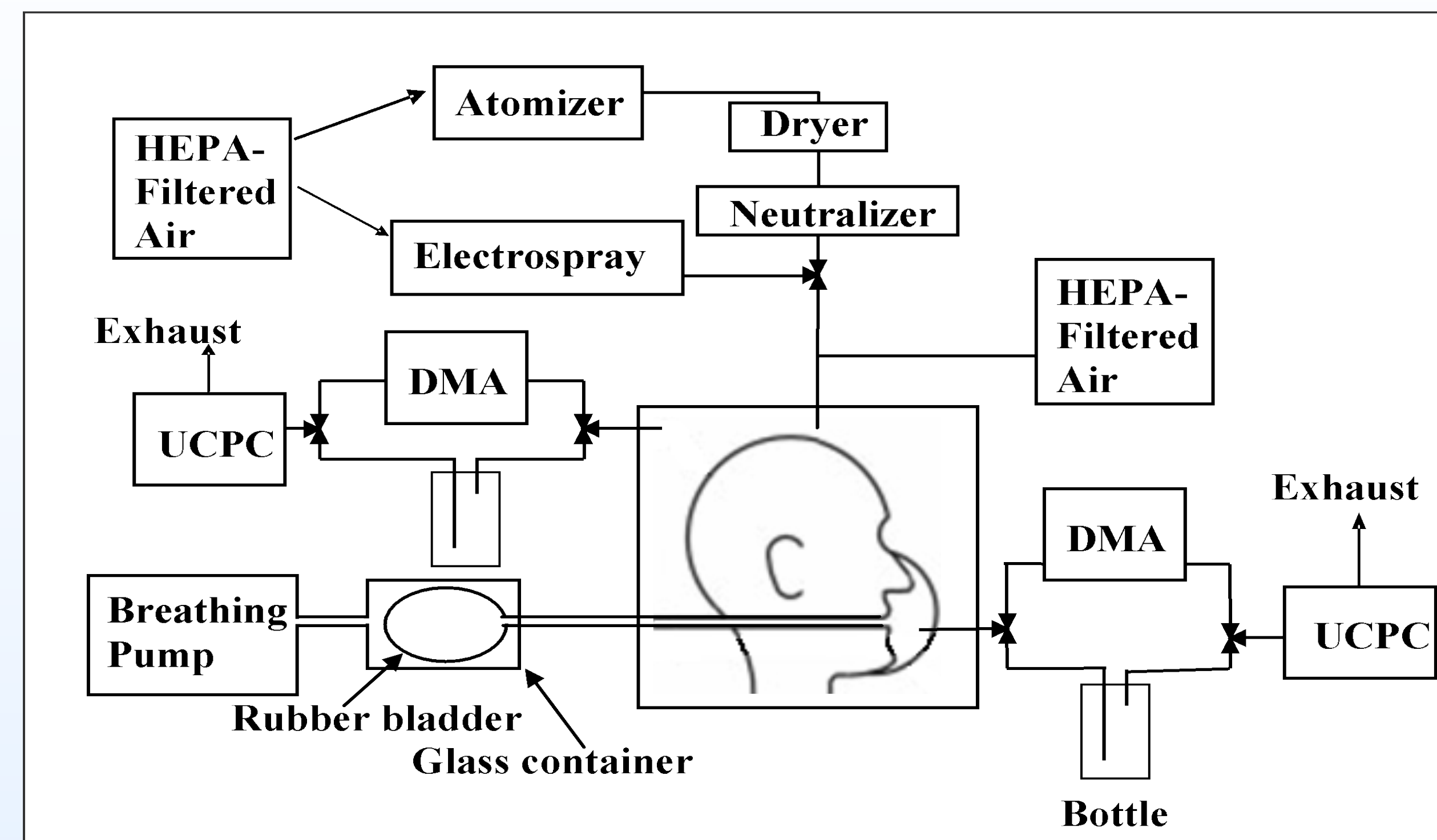


Fig 2. Flow diagram of the experimental setup for measuring total inward leakage of nanoparticles.

Results

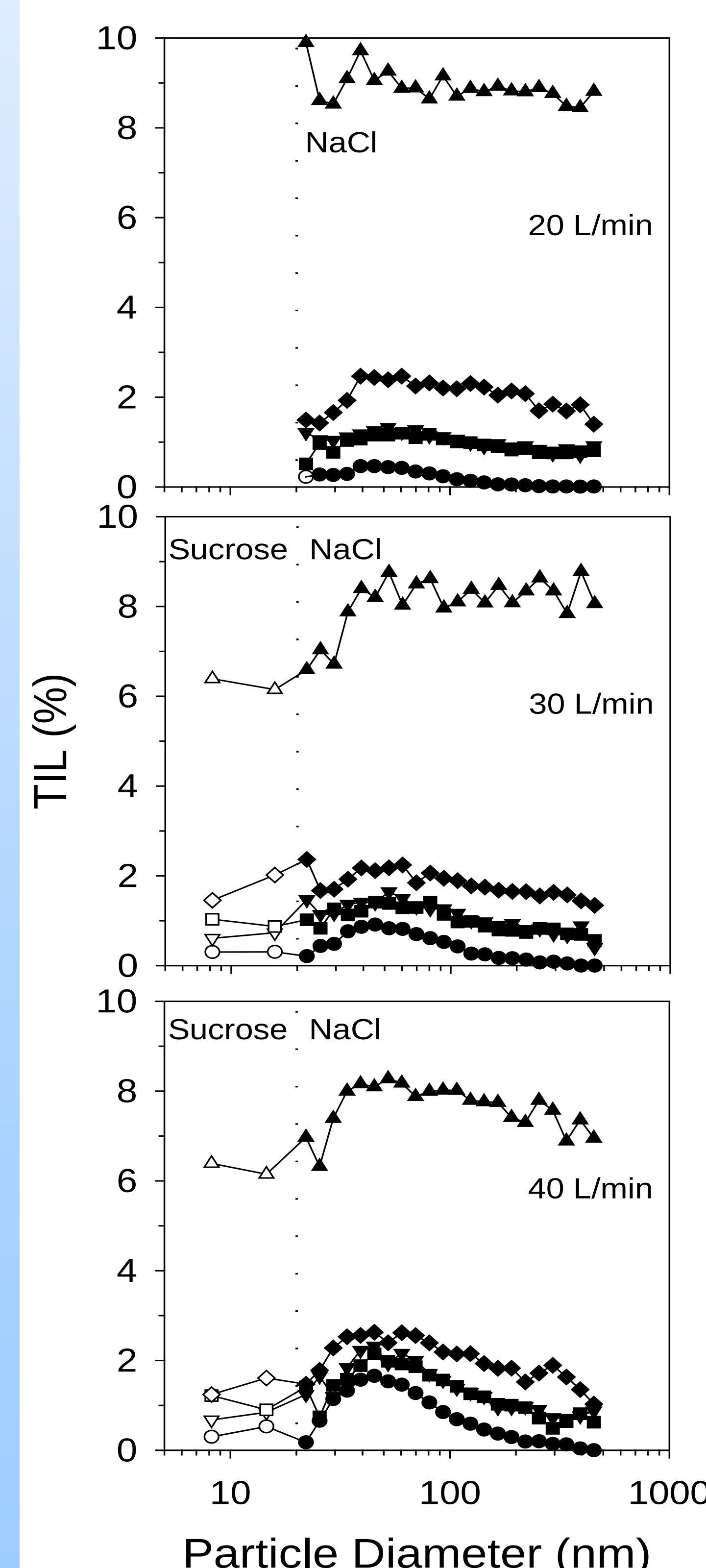


Fig 3. Typical TIL values for a N95 FFR at 20 L/min (top), 30 L/min (center) and 40 L/min (bottom) minute volume with different leak sizes. Polydisperse NaCl aerosols from an atomizer was used for sizes >20 nm (filled symbols), and monodisperse sucrose aerosols from an electro spray was used for particles <20 nm (open symbols).

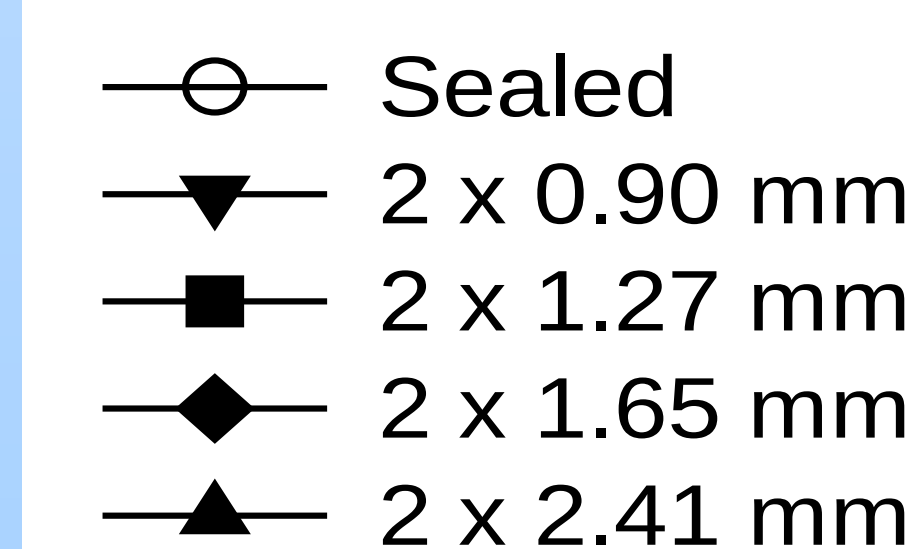


Table 1. Average filter penetration and TIL values for 50, 100 and 400 nm size particles for one N95 FFR model.

Leak Size (mm)	Flow Rate (L/min)	TIL (%)			TIL/penetration Ratio		
		Particle Size (nm)					
		50	100	400	50	100	400
Sealed Penetration (%)	20	0.57	0.24	0.05			
	30	0.94	0.46	0.05			
	40	1.60	0.66	0.09			
Leak size 1 (2 x 0.90)	20	1.14	0.94	0.72	2.1	4.3	54.5
	30	1.53	1.02	0.77	2.2	3.4	26.0
	40	1.85	1.21	0.71	2.3	3.5	23.9
Leak size 3 (2 x 1.65)	20	2.01	1.84	1.71	3.7	8.7	142.6
	30	2.01	1.78	1.58	2.9	6.0	68.8
	40	2.33	1.94	1.43	2.9	5.9	68.6
Leak size 4 (2 x 2.41)	20	7.62	7.68	7.76	14.3	38.4	693.9
	30	6.97	7.18	7.16	10.0	26.2	412.1
	40	7.07	6.88	6.69	8.7	22.7	460.7

Note: Leak size two was excluded due to its proximity to Leak size 1.

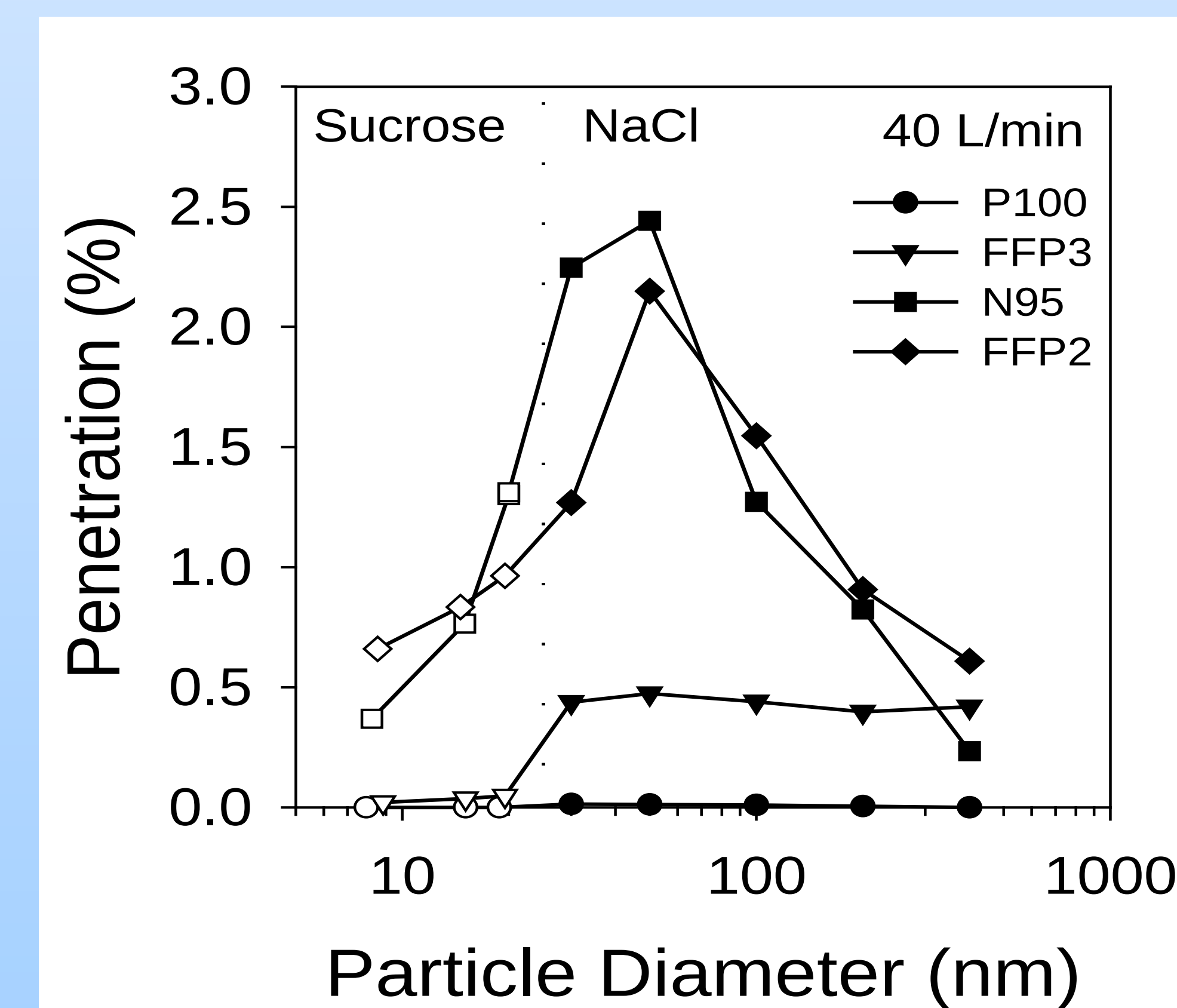


Fig 4. Typical filter penetration levels for the four FFR models at sealed conditions at 40 L/min breathing flow rate. NaCl (filled symbols) and sucrose particles (open symbols).

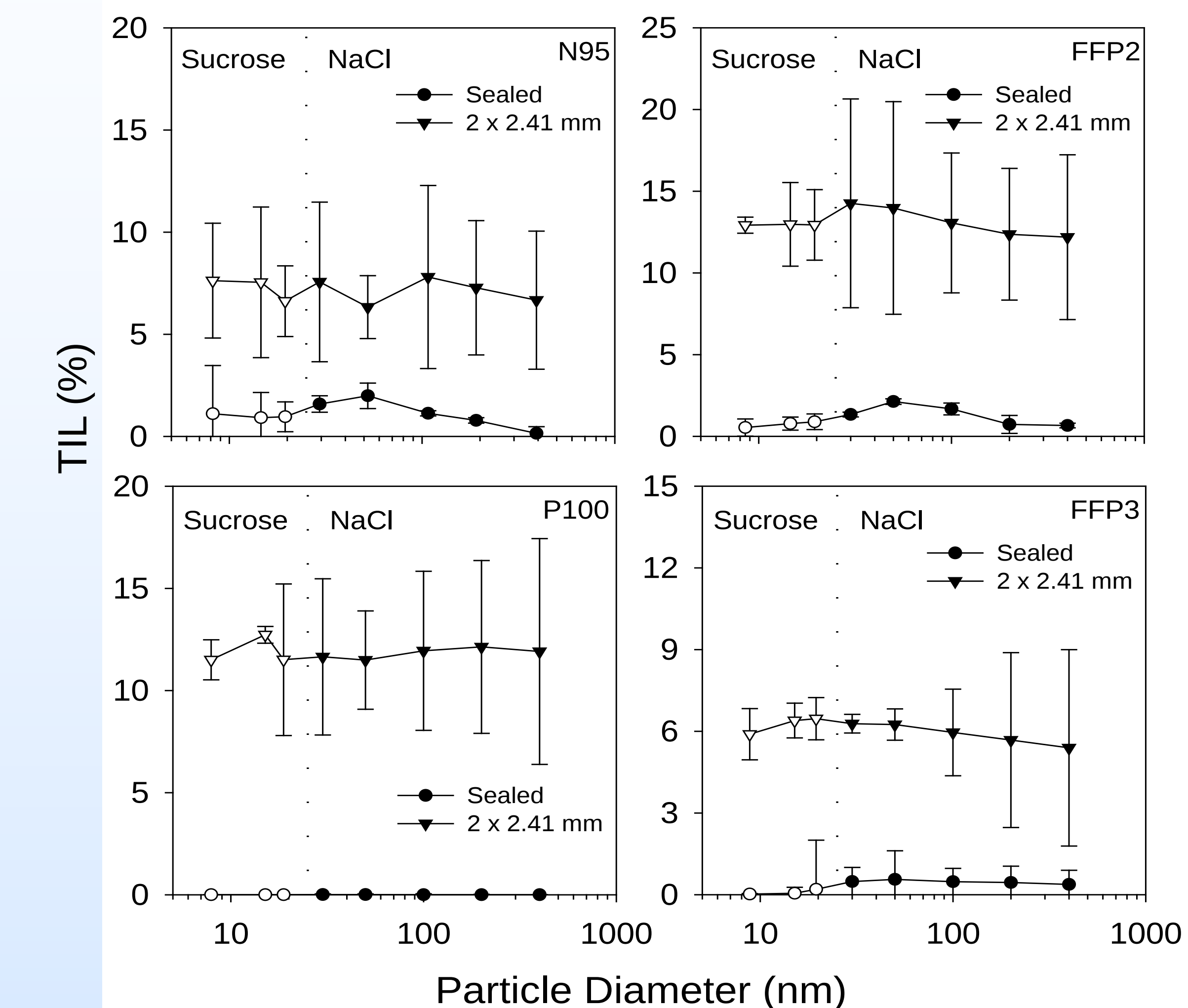


Fig 5. Comparison of TIL values for the four FFR model respirators against NaCl (filled symbols, 20-400 nm size) and sucrose particles (open symbols, 8-20 nm size) at sealed and at two 2.41 mm leak sizes at 40 L/min breathing flow rate.

Conclusions

- Filter penetration levels for 50 nm size particles (MPPS) was markedly higher than the values obtained for 400 nm size particles
- Filter penetration increased with increasing flow rate for all size particles
- TIL value for nanoparticles (<100 nm size) was higher than the value for 400 nm size particles indicating higher levels of nanoparticles in the breathing zone
- TIL value for nanoparticles was influenced by particle size, leak size and flow rate
- TIL/penetration ratio consistently increased with increasing particle size indicating less leakage for nanoparticles than for larger (400 nm) size particles

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